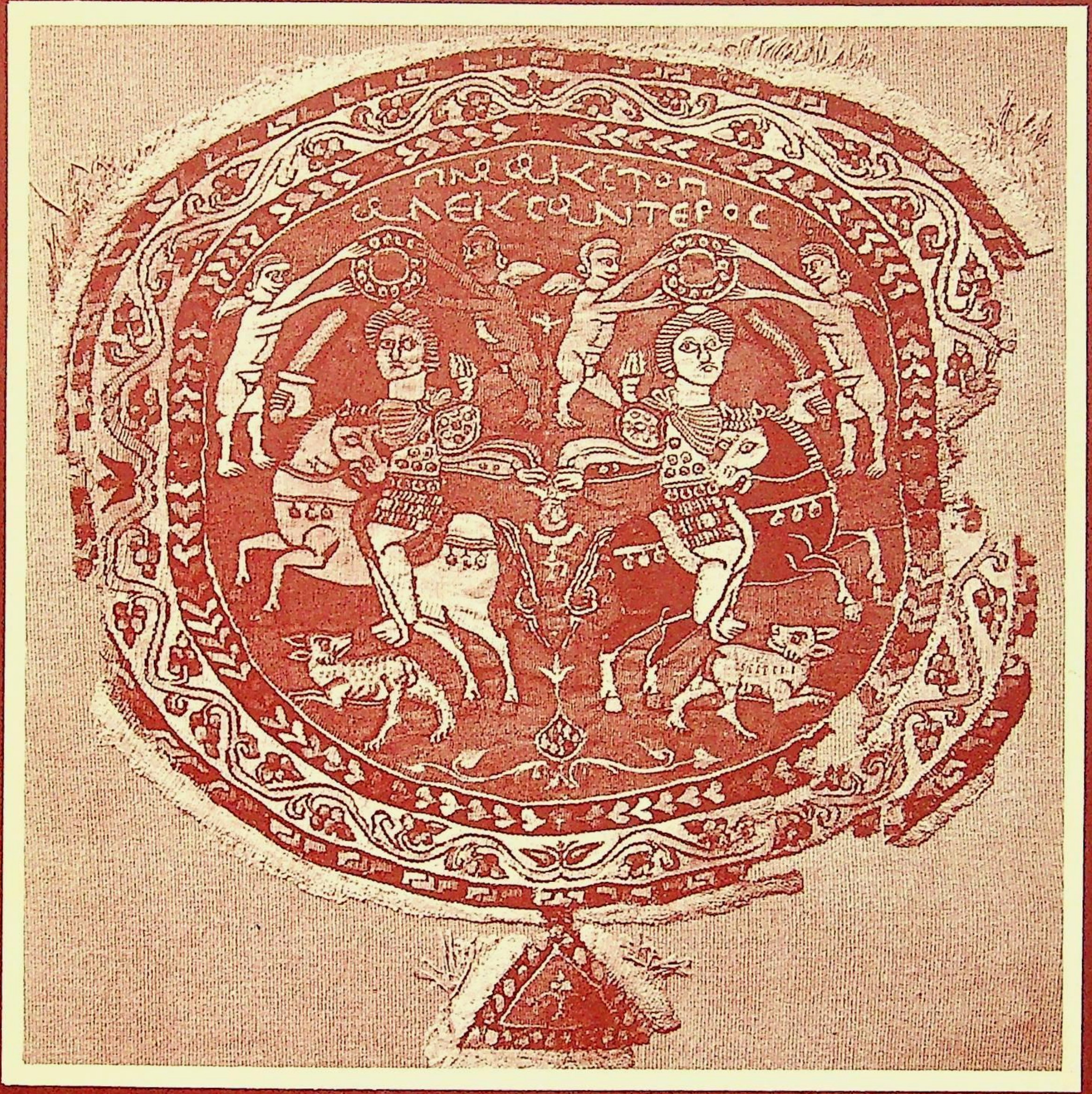
TEXTILE MUSEUM JOURNAL



Decorative Tapestry. Alexander the Great Hunting. Egypt, 8th to 9th century (?) T.M. 11.18

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PRINCIPLES OF TEXTILE CONSERVATION SCIENCE NO. I

GENERAL CHEMICAL AND PHYSICAL STRUCTURAL FEATURES OF THE NATURAL TEXTILE FIBERS

James W. Rice

1. WHAT IS INVOLVED IN HISTORICAL TEXTILE CONSERVATION?

Conservation of textiles involves:

a. Cleaning and removal of foreign matter
b. Restoration of colors
c. Arresting natural degradation processes
d. Reversing, where possible, aging influences
e. Repairing results of deterioration
f. Preparing specimens for display and study
g. Packaging and storing specimens

Problems in textile conservation involve cleaning and removal of foreign matter without changing or damaging the specimen. Also we hope to brighten faded or dulled colors, if we can, and stop deterioration where possible. We dream of reversing the effect of time, either by chemical processes or by actual physical mending. We try to put the textile sample in the best possible condition for inclusion in displays, for studies as to spinning and weaving techniques and for shipping and storage.

Success in overcoming these problems depends upon the conservator's knowledge of fundamentals of chemistry and physics and his ability to apply scientific principles to their solution. This particular technical paper is one of a series of publications dealing with numerous aspects of textile conservation both from the theoretical and practical points of view and is intended as an introduction to future papers and discussions.

2. WHY ARE THEORIES IMPORTANT IN CONSERVATION WORK?

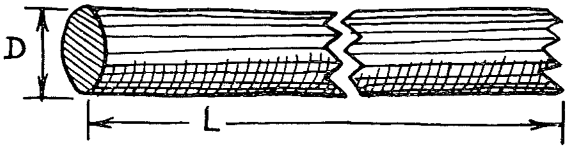
Fiber structure theories explain reasons for:

a. Choice of conservation chemicals
b. The conditions for using these chemicals
c. The effect of the several fiber destructive influences
d. The precautions to be taken in handling fragile fabrics

Theories as to the origin, composition and structure of the various things we work with are valuable in helping us to understand why certain materials behave as they do. Those of us who are interested in the study of old textiles will probably have use for explanations of the construction and composition of the natural fibers so that we can think out how chemicals and natural processes affect the strength and aging qualities of the fabrics; in what ways they accept colors, dyes and stains and what precautions we must take in cleaning and preserving them. Perhaps a review of the more reasonable theories pertaining to the common natural fibers will provide the mental tools for solving some of these problems.

3. WHAT IS A FIBER?

A fiber is a fine threadlike structure:



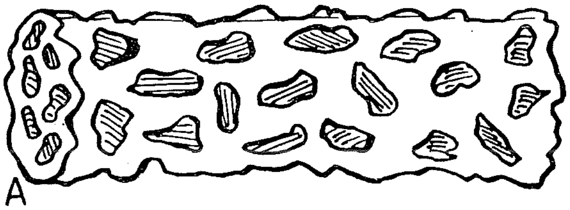
where L exceeds 100 D.

Fabrics are made up of fibrous substances, so perhaps a definition of what we think of as a fiber and a discussion of some of its outstanding characteristics is in order. By means of low powered magnification we may observe that the familiar natural fibers are slender, rod-like particles of matter that are at least 100 times as long as they are thick. As a matter of fact, the stronger and more useful fibers are very much longer in comparison. Although the natural fibers are complex and differ among themselves markedly in many ways, there are certain structural resemblances that enable us to explain common behavior patterns.

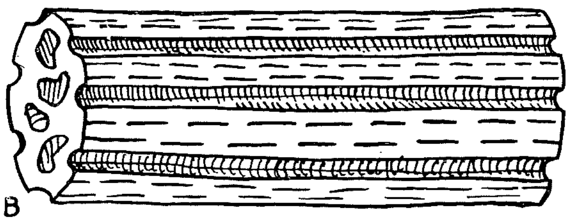
4. WHAT IS THE MOST IMPORTANT CHARACTERISTIC OF THE NATURAL FIBER?

The first and most important of these likenesses is porosity. This has a profound bearing on the success of conservation efforts, since it governs the ease or difficulty of penetrating the interior of the fiber structure. Porosity also controls the dyeing and color retention qualities of the fiber. It affects moisture absorption, fungus and bacterial infection and rapidity of oxidation or rotting. Because we think of the fiber as being porous, we conceive it to contain open spaces which may be irregular in shape but in some cases may be continuous so as to form extremely fine capillaries.

The natural fibers, wool, hair, silk, cotton, linen, hemp and barks are porous. Their surfaces are seldom precisely smooth and interior pores (a) may be irregularly shaped, randomly spaced and disoriented:

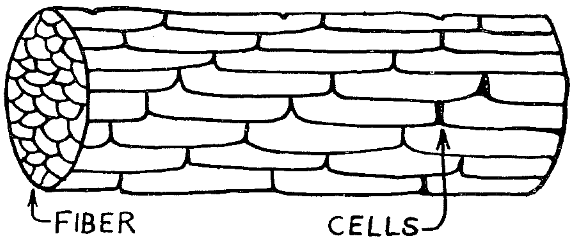


or (b) striated and grooved with relatively long longitudinal pores:



5. WHAT IS A FIBER CELL?

The solid or more rigid portions of the fiber including its outer skin or cuticle material is considered by many textile students as being composed of cells, which consist mainly of bundles or arrangements of molecules of a principal chemical compound. In the case of the vegetable fibers, this chemical is cellulose, whereas the animal fibers are made up of proteins which are very different in chemical character from the cellulose. Because these cells are formed by living organisms they are not one single chemical but contain small amounts of other substances which are necessary in the life and growth processes of the plant or animal. These last constitute impurities which often require treatment of the fiber before it is suitable for working into yarns and fabrics. It may be that the impurities may occupy the spacings between cells rather than inside them.



In the natural growth cycles of the fiber, cells formed from chemical molecules are in turn built into the fiber structure.

6. WHAT IS A FIBRIL?

A relatively long and slender cell is sometimes called a fibril, perhaps because it resembles a fiber in shape. Fibrils can sometimes be seen under high magnification when a true natural fiber has been macerated mechanically or damaged by fungus or chemicals.

Fibrils are thread-like particles of natural fibers (Fig. 6 a and b):

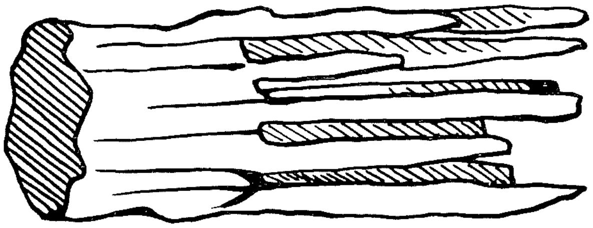


Fig. 6 a. Fibrils formed as a result of wear and abrasion.

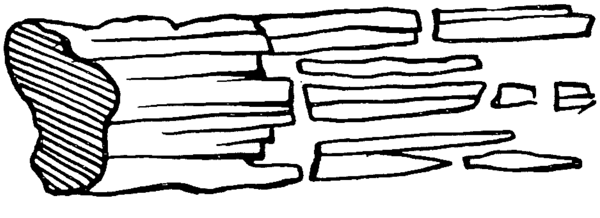


Fig. 6 b. Fibrils formed as a result of mildew and fungi.

7. WHAT ARE THE CHARACTERISTICS OF FIBER MACROPORES?

There are at least two kinds of pores in the fiber. The relatively large ones such as may exist between cells are called "macropores" or "macrocapillaries." These are large enough to permit entry of collected bundles of chemical molecules or micelles such as colloidal solutions are supposed to be made up of. Almost all soap and detergent solutions, gels, starches, dye baths and many other useful textile treatment agents are used and applied as colloidal solutions that can be accepted by these "macropores." A colloidal solution differs from a true solution in that the latter is considered as a dispersion of many single chemical molecules in a liquid medium, whereas the former may be composed of dispersions of bundles of a number of molecules collected together in a solvent, usually water. A true solution can be distinguished from a colloidal mixture by the Tyndall effect in which a beam of light shines through a glass tube containing the solution. A true solution will show no light scattering and its path is not seen. A colloidal solution will show a cloudy path. This is interpreted as indicating that the molecules of a true solution are smaller in dimensions than the wave length of light and therefore do not affect its travel. The bundles or micelles in the colloidal mixture are larger and will cause light scattering which can be detected. Colloidal solutions have been shown in recent years to have profound influences on surfaces, especially those of fibers. These will be described in detail in a later paper on detergency.

Characteristics of "Macropores" (Fig. 7 a, b and c):

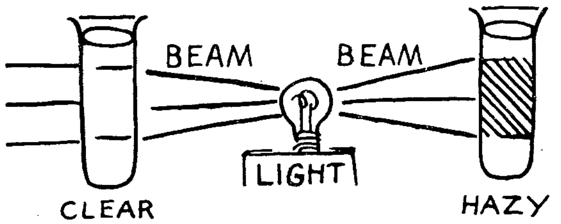


Fig. 7 a. True molecular solution and clear colloidal dispersion.

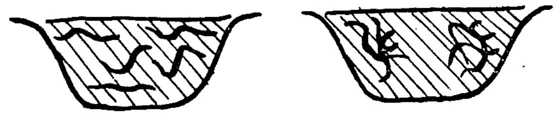


Fig. 7 b. Single molecules, and micelles which are bundles of molecules.

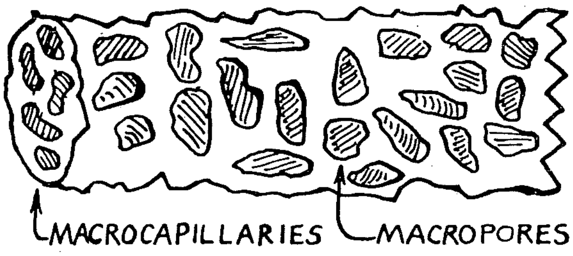


Fig. 7 c. The "marocapillaries" or "macropores" permit penetration by molecules or very small "micelles" of soap and dyes.

8. WHAT ARE THE OUTSTANDING CHARACTERISTICS OF THE CHEMICAL MOLECULES COMPOSING A FIBER SUBSTANCE?

Molecules are generally defined as the smallest particles into which a chemical compound can be divided without losing its identity. If broken down further, it takes on new properties and characteristics. In general, simple molecules follow this conception. However, our mental picture of the fiber molecules is more complicated because we think of them as long chains, composed of relatively simple molecules which resemble one another either exactly or perhaps very closely and which are joined end to end. In this process, two adjacent small molecules combine to form links in a chain and in doing so produce a molecule of water. The water disappears in exhalation or evaporation from the living plant or animal and since it can be recovered if desired by condensing it on a cold surface, the mechanism of natural synthesis is called condensation. In the growth cycle, this reaction requires energy such as light and heat together with triggering chemicals which we call catalysts. These long chain type complex molecules are sometimes called polymers and the process is also called polymerization. This is the basis for the chemistry of modern plastic and synthetic fiber manufacture, although the junctions between small molecules may not be by the same condensation or elimination of water mechanism.

The chain-like construction of the synthetic fiber molecules is illustrated by the development of cellulose:

a. A small soluble chemical molecule such as glucose sugar $C_6H_{12}O_6$ is formed as a plant juice. This may be represented by H—O—⬡—O—H. It is the building block for the cellulose molecule.

b. When the right conditions prevail in nature, two or more of these will join up.

H—O—⬡—O—H + H—O—⬡—O—H →
2 glucose molecules join to give
H—O—⬡—O—⬡—O—H + H—O—H
a sugar a molecule of water.
(N) H—O—⬡—O—H →
a large number of glucose molecules combine to give H—O—⬡—O . . . —⬡—O—H + (N—1) H—O—H a cellulose fiber molecule N fragments long plus one less than that number of molecules of water. The glucose units represent links in a chain. Where N or the number of links is about 2200, we have strong cotton or linen fiber. If N is 900, we may have ordinary rayon or paper cellulose.

9. HOW ARE THESE MOLECULES ARRANGED IN THE LIVING CELL?

In the living plant or animal, the fiber structure is built up of bundles of molecules arranged in a more or less parallel fashion and held together across the bundles, in some cases by inter molecular attractions and in others by chemical bonding. The strength and resistance to aging and other destruction forces, possessed by the fiber, depends on the length of the molecule and the density of packing within the natural bundle or micelle. Normally the natural fiber molecules are very long as molecules are measured, but their density of packing within the micelle structure is loose. This allows for spaces between the fiber molecules which we visualize as "micropores" and which are too fine to be penetrated by large molecules or micelles of other substance but can be entered by relatively small molecules, as for example, those of mineral acids, alkalies, water and oxygen from the air or in a true solution. Larger molecules that tend to form into bundles or micelles such as soaps, detergents, dyes and other surface active chemicals are not apt to penetrate the "micropores" but may be worked into the macropores or spaces between the cells as mentioned before.

How nature arranges the fiber molecules to form the extremely fine spacings within the cell. (Fig. 9a, b, c, d):

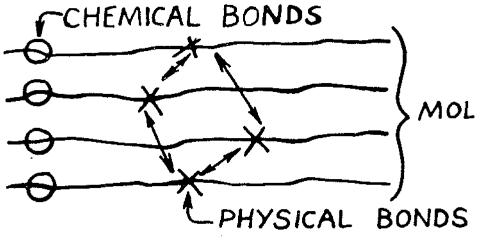


Fig. 9 a. (An idealized sketch of the molecules, in the crystal.) The long chain-like molecules, in general, attempt to arrange themselves according to a crystaline pattern. The crystal is a geometric solid with the molecules arranged in a definite direction and spacing.

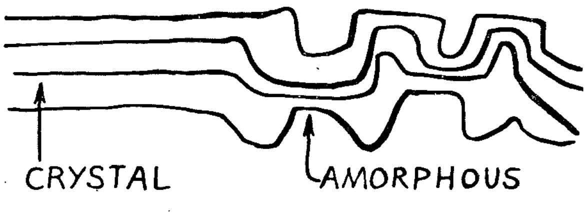


Fig. 9 b. Unfortunately X-ray diffraction studies of fiber indicate a mixture of some crystalinity and some molecules haphazardly arranged in an amorphous or non-crystaline pattern. Thus we may have bundles of molecules composed of each kind of arrangement. These we call micelles.

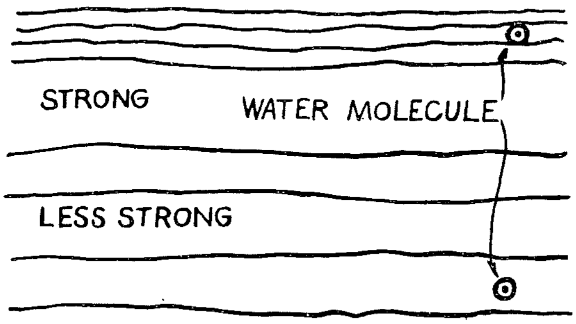


Fig. 9 c. Very closely laid molecules produce crystals or micelles that form strong and durable fibers. The intermolecular spaces are close together and are not easily penetrated except by the very smallest of chemical molecules. Spacings close together may allow water or mineral acids or alkalies to enter. Spacings far apart permit entry of molecules of more complex chemicals.

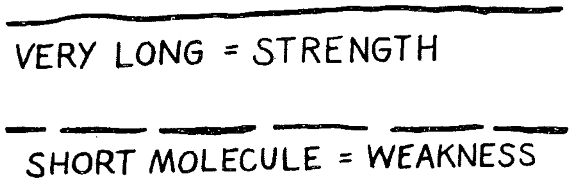


Fig. 9 d. A fiber formed of long molecules is strong; a fiber formed of short molecules is weak.

10. HOW IS FIBER DETERIORATION AFFECTED BY ITS STRUCTURE?

When some of the types of potentially destructive chemical molecules penetrate the fiber micelles, the bonds between the fiber molecules are weakened and some of the junctions within the long chain molecules may be broken. An example of this is where a mineral acid in water solution reverses the synthesis mechanism in which the junction points between links in the cellulose molecules are parted and split, molecules of water are substituted between the two links to satisfy the chemical valence bondings. At this point we should note that this particular chemical action is opposite to condensation as described earlier. It is called hydrolosis because water is split or consumed in the process. The net effect is to weaken both the fiber molecules and their micelles and perhaps cause them to become brittle. These theories of fiber structure and porosity are fundamental and are the result of studies by many famous textile authorities over more than the past century. With this brief resumé of these studies, we hope to lay a foundation for more practical future advice and solutions to specific conservation problems.

Fiber destructive forces act in two ways. Referring back to Fig. 9 a, we visualize the crystal broken up first, by disruption of cross bonds between molecules as indicated in Fig. 10 a:

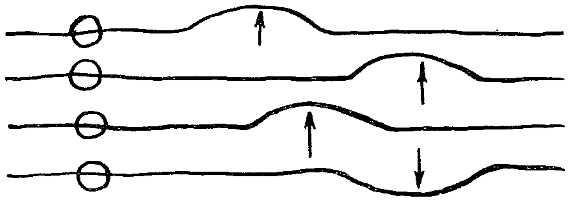


Fig. 10 a. Physical bonds disrupted—weaker crystal. Any strong disruption force such as parting of a cross bond between two or more molecules in the crystal or micelle form will weaken the bundle. The actual substances and forces that act in this manner will be discussed later in this series of papers.

Second, as in Fig. 10 b, by breaking the fiber molecules into shorter fragments by means of any chemical action that can reverse the condensation or polymerization processes described in paragraph 8, as for example:

H—O—⬡—O—⬡—O—⬡—O—⬡—O—⬡ . . . etc.

. . . O—H plus mineral acid and H—O—H (water) form H—O—⬡—O—H, H—O—⬡—O—H . . . etc.

H—O—⬡—O—H (molecules of glucose sugar which are soluble.)

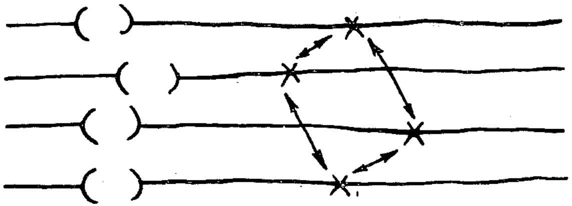


Fig. 10 b. Chemical bonds broken—brittle crystal.